Report for 2001MT241B: Determination of the maximum weight radio transmitter that can be implanted in westslope cutthroat trout without affecting swimming performance: A challenge to the "2% rule"

There are no reported publications resulting from this project.

Report Follows:

DETERMINATION OF THE MAXIMUM-WEIGHT TELEMETRY TRANSMITTER THAT CAN BE IMPLANTED IN WESTSLOPE CUTTHROAT TROUT WITHOUT AFFECTING SWIMMING PERFORMANCE: A CHALLENGE TO THE "2% RULE"

FINAL REPORT

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Abstract

We empirically determined the relationship between radio transmitter weight and swimming stamina in telemetered westslope cutthroat trout in the laboratory to facilitate field studies of movements and behavior of this rare native fish. Telemetry studies of small fish are limited primarily by transmitter battery life, which is a function of battery weight. Untested dogma holds that transmitter weight should not exceed 2% of the total body weight of a telemetered fish. We found that telemetry transmitters comprising up to about 5% of total body weight had only minor effects on swimming stamina and growth of westslope cutthroat trout. No threshold beyond which performance deteriorated markedly was observed. Researchers need not be bound strictly by the old “2% rule-of-thumb” but should bear in mind that any increase in transmitter weight will impair physiological performance of telemetered fish, albeit perhaps only slightly. Any benefits of increased transmitter weight should be balanced against such physiological impairments.

Problem and Research Objective

Westslope cutthroat trout *Oncorhynchus clarki lewisi* historically inhabited streams of the upper Missouri River Basin, including the Gallatin and Madison river drainages. Westslope cutthroat trout currently occupy only about 27% of their historical range in Montana. Competition with introduced trout species has contributed to this decline, but the specific mechanisms responsible for displacement are not well understood. Loss of genetic integrity through hybridization is a major problem where westslope cutthroat trout and introduced rainbow trout *O. mykiss* occur sympatrically. Various State and federal agencies are working to maintain and restore westslope cutthroat trout within their native range in Montana.

Genetic sampling of putative westslope cutthroat trout by the National Park Service in streams of the upper Missouri River Basin in the northwest corner of

Yellowstone National Park revealed that only one stream in the Park, the North Fork of Fan Creek in Montana, contains a genetically pure population. The genetic purity of the North Fork Fan Creek population is surprising, considering that the site is not isolated by a physical barrier (e.g., an insurmountable waterfall) preventing invasion by non-native fishes from downstream. This suggests that the population is reproductively isolated either temporally or spatially. That is, the westslope cutthroat trout in this population either spawn in different places or at different times than introduced rainbow and Yellowstone cutthroat trout in this system. Determination of the exact mechanism responsible for this reproductive isolation is essential to maintaining the purity of this population and for duplicating this phenomenon in other streams where pure westslope cutthroat trout are being reintroduced or managed in Montana. Accordingly, we are studying spawning timing and movements of this population.

The primary means by which spawning timing and location are documented is by radio telemetry. Fish are implanted with radio transmitters prior to spawning and followed to their spawning sites. A problem with this technique is that westslope cutthroat trout in small headwater streams are invariably small ($\leq$100 g) and therefore cannot be implanted with large transmitters that transmit for long durations; transmitter life is a function of battery size. Conventional wisdom suggests that weight of transmitters should not exceed 2% of the body weight of fish to preclude any effects on swimming performance, survival, and behavior (Winter 1983), but this rule-of-thumb is based on no hard evidence. Trials conducted with very small rainbow trout (5-10 g) suggested that greater transmitter weights may be acceptable (Brown et al. 1999). If we followed the “2% rule,” maximum transmitter weights that could be used in Fan Creek westslope cutthroat trout would be 2 g, with maximum transmission durations of about 100 days. However, 4-g transmitters would transmit for about 280 days, and therefore allow earlier implantation, more time for recovery after surgery before spawning, and monitoring of post-spawn movements to determine habitats used during subsequent seasons.

Our objective was to determine empirically the relationship between transmitter weight and swimming stamina in westslope cutthroat trout. Understanding this relationship would allow implantation of the maximum weight transmitter that would not affect the physiological performance of a telemetered fish and thereby gain the maximum amount of telemetry information from that fish. Such information could be used to facilitate restoration and management of this native salmonid.

Methodology

Test fish were obtained from the Montana Fish, Wildlife & Parks Washoe Park Hatchery in Anaconda, which maintains a pure stock of westslope cutthroat trout (Strain M012, Lot M010199Z), and transferred to the Wild Trout Research Laboratory on the Montana State University campus in Bozeman for testing. They were maintained for 2 weeks prior to transmitter implantation in a 465-L fiberglass tank supplied with oxygenated and filtered 13 °C water from by the laboratory's recirculating process system; the water turnover time in the tank was 20 minutes. Experiments were conducted in a swimming stamina tunnel at the laboratory supplied with the same water source. The fish chamber of the tunnel had an inner diameter of 108 mm and a length of 132 cm. It was powered by a 2-horsepower jacuzzi pump. Swimming stamina tests are a convenient and accepted means to assess the physical condition of fish and are a good indicator of stress (Wedemeyer et al. 1990).

The fish were 22 months old at the time of transmitter implantation and averaged 240 mm in total length and 132.8 g in weight (Tables 1 and 2). They were randomly assigned to 7 groups including a control group (no surgery, no transmitter), a group on which surgery was performed but no transmitter was implanted (sham surgery), and 5 groups surgically implanted (into the peritoneal cavity) with transmitters weighing 1, 2, 3, 4, or 5 g. No significant difference existed among mean initial weights of the treatment groups (P=0.7427; Figure 1). Initial transmitter burdens, expressed as percent body weight, ranged from a mean of 0.77% in the 1-g treatment group to 4.05% in the 5-g treatment group (Table 3). We used standard surgical implantation techniques (Winter 1983) and closed incisions with surgical staples. The transmitters were non-functional facsimiles made of lead shot imbedded in epoxy; their size, shape, and density mimicked those of commercially manufactured radio transmitters with coiled-loop antennae (no trailing external antenna). All fish except controls were injected with a passive integrated transponder (PIT) tag to permit individual identification. Several fish died during or immediately after surgery and were discarded. Numbers of fish in each treatment group one day after implantation were as follows: control 15, sham 14, 1-g 14, 2-g 15, 3-g 14, 4-g 17, and 5-g 15. Following surgery, fish were allowed to recover for 2 weeks in the holding tank prior to initial performance testing. A second trial was conducted 6 weeks after implantation. Fish were fed a standard trout feed (Silver Cup) at a rate of 1% of body weight per day.

Fish were tested in the stamina tunnel individually at a water velocity of 90 cm/second. Preliminary trials indicated that this velocity would be sensitive to differences among individuals (i.e., times to fatigue were not so short that differences were indistinguishable) but also insured that exhaustion would be achieved within 10 minutes. After introduction of the fish to the tunnel, the water velocity was instantaneously elevated to the test velocity and a timer was started. The fish was identified with a PIT-tag reader while in the tunnel. The challenge was terminated when the fish stopped swimming and permanently came to rest against the tail grate of the tunnel. The fish was then expelled from the tunnel by removing the tail grate and weighed and measured. Fish were immediately returned to the holding tank after the 2-week trials and sacrificed and dissected after the 6-week trials to verify transmitter weights and presence.

Times to fatigue were compared among treatment groups using analysis of variance. Regression analysis was used to discern if a relationship existed between times to fatigue and relative transmitter burdens. Controls, but not sham-surgery fish, were excluded from the regression analysis to preclude confounding. Statistical analyses were performed using SAS software.

Principal Findings and Significance

Several fish died during the first 2 weeks after transmitter implantation and before the first stamina trial. These included one control, two sham-surgery, one 3-g treatment, and three 4-g treatment fish. In addition, one 3-g treatment fish expelled its transmitter through its implantation incision, which had failed to heal properly. These fish were excluded from further analyses. Numbers of fish in each treatment group in the 2-week stamina trials were as follows: control 14, sham 12, 1-g 14, 2-g 15, 3-g 12, 4-g 14, and 5-g 15.

No significant difference existed among the mean times to fatigue of the different treatment groups 2 weeks after implantation (P=0.1234; Figure 2). Fish with 2-g or larger transmitters tended to tire faster than fish with 1-g or no transmitters, but the difference was not significant and did not become more pronounced with increasing transmitter burden (Figure 2). Regression analysis of time to fatigue versus transmitter burden 2 weeks after implantation indicated a negative relationship; each percent increase in tag-to-body weight ratio resulted in a 5.0% decrease in time to fatigue. However, the relationship was not significant (P=0.0957) and explained only 3.6% of the variability among individuals (Figure 3). Fish with similar transmitter burdens tired over a wide range of times.

No significant difference in mean weights existed among the treatment groups 2 weeks after implantation (P=0.2992; Table 2, Figure 1). However, a significant negative relationship existed between mean daily individual growth rates during the first 2 weeks after implantation and relative initial transmitter burdens (P=0.0344); the relationship explained 5.6% of the variability among individuals (Figure 4). Each percent increase in tag-to-body weight ratio resulted in a 13.4% decrease in growth rate.

One control fish died between the 2-week and 6-week stamina trials. Transmitters were lost through ruptured incisions by one 1-g, two 3-g, and one 4-g treatment fish, and single 3-g and 5-g treatment fish expelled their transmitters through their vents. These fish were excluded from further analyses. Numbers of fish in each treatment group in the 6-week stamina trials were as follows: control 13, sham 12, 1-g 13, 2-g 15, 3-g 9, 4-g 13, and 5-g 14.

No significant difference existed among the mean times to fatigue of the different treatment groups 6 weeks after implantation, but the differences approached significance (P=0.0541; Figure 2). Fish with 2, 3, and 4 g transmitters tended to tire faster than fish with no, 1-g or 5-g transmitters. Regression analysis of time to fatigue versus transmitter burden 6 weeks after implantation indicated a negative relationship that approached significance (P=0.0682) but explained only 4.6% of the variability among individuals (Figure 3). Each percent increase in tag-to-body weight ratio resulted in a 5.6% decrease in time to fatigue.

Mean weights of tested fish (Table 2, Figure 1) were not significantly different among treatment groups 6 weeks after implantation (P=0.2639). However, a significant negative relationship existed between mean daily individual growth rates between the two stamina trials and relative initial transmitter burdens (P=0.0098) that explained 8.2% of the variability among individuals (Figure 4). Each percent increase in tag-to-body weight ratio resulted in a 10.3% decrease in growth rate. A similar relationship existed between growth rates during the full 6-week period and initial relative transmitter burdens (P=0.0014, r^2=0.1217); growth decreased 11.6% with each 1% increase in tag-to-body weight ratio.

The principal conclusion of our study is that telemetry transmitters comprising up to about 5% of total body weight had only minor effects on swimming stamina and growth of westslope cutthroat trout. No threshold beyond which performance deteriorated markedly was observed. Researchers can therefore likely double the size of transmitters recommended by the old “2% rule-of-thumb” apparently without drastically impairing physiological performance of telemetered fish. This increase in transmitter size substantially lengthens the durations that telemetered fish can be tracked, thereby increasing the quantity and utility of data each telemetered fish yields at only slightly increased cost (for larger batteries) and only slightly decreased physical status. In the case of small, headwater-dwelling westslope cutthroat trout, this trade-off may be acceptable and warranted. However, we strongly caution against exceeding 5% of body weight because our study did not evaluate effects beyond this level. Furthermore, our findings suggest that any incremental increases in transmitter-to-body weight ratio, including those below 2%, may have deleterious effects on telemetered fish. Therefore, researchers should always choose the lightest possible transmitters that allow study goals to be achieved.

We failed to determine the maximum weight transmitter that could be implanted in westslope cutthroat trout without eliciting clearly deleterious effects because we did not challenge fish with an excessively high transmitter burden. Whether swimming stamina would decline gradually or drop precipitously beyond some threshold transmitter burden is unknown. Additional trials with larger transmitters or smaller fish are needed therefore. We also recommend using more fish in stamina trials of this type because individual variability in stamina is high; larger sample sizes would enhance detection of genuine effects.

Publications and Citations

None thus far, but we intend to submit a manuscript on this work to a major fisheries science journal shortly.

Student Support

Ms. Carrie Brooke, a M.S. graduate student in the Fish & Wildlife Management Program in the Department of Ecology at Montana State University, conducted the implantations and stamina trials. She thereby gained valuable training in experimental design, laboratory techniques and protocols, and statistical analyses.

In addition, the findings allowed her to implant larger transmitters in the westslope cutthroat trout she is studying for her thesis research.

Notable Achievements and Awards

Our findings have been communicated informally among fisheries scientists in Montana and the region. Researchers are already using heavier transmitters in current telemetry studies based on our results. Our study has thereby already enhanced the ability of fisheries scientists and managers to investigate fishery problems related to fish migration, movements, and behavior.

Literature Cited

Brown, R. S., S. J. Cooke, W. G. Anderson, and R. S. McKinley. 1999. Evidence to challenge the “2% rule” for biotelemetry. North American Journal of Fisheries Management 19:867-871.

Wedemeyer, G. A., B. A. Barton, and D. J. McLeay. 1990. Stress and acclimation. Pages 451-489 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

Winter, J. D. 1983. Underwater telemetry. Pages 371-395 *in* L. A. Nielsen and D. L. Johnson, editors. Fisheries techniques. American Fisheries Society, Bethesda, Maryland.

Table 1. Mean total lengths (mm) and standard deviations and ranges of total lengths of each treatment group of westslope cutthroat trout at time of transmitter implantation and 2-week and 6-week stamina trials.

Treatment	Implantation	2 Weeks	6 Weeks
Control	240.3	242.1	250.4
	15.6	14.1	16.0
	210-265	215-265	220-280
Sham	240.0	246.2	252.5
	16.2	13.7	11.8
	210-260	225-265	235-270
1 gram	244.3	244.3	251.2
	22.0	22.6	22.2
	210-280	210-285	220-290
2 gram	242.7	242.8	246.1
	14.5	14.4	16.7
	220-275	225-270	220-275
3 gram	237.1	237.5	246.1
	13.0	13.2	8.6
	220-260	220-255	230-255
4 gram	238.5	237.1	242.3
	11.7	14.0	16.3
	220-255	210-260	215-270
5 gram	236.5	234.6	239.6
	14.6	13.1	16.3
	220-265	220-265	220-270

Table 2. Mean total weights (g) and standard deviations and ranges of total weights of each treatment group of westslope cutthroat trout at time of transmitter implantation and 2-week and 6-week stamina trials.

Treatment	Implantation	2 Weeks	6 Weeks
Control	128.1	134.8	163.7
	26.1	20.5	26.6
	81.3-165.6	98.5-167.2	107.9-201.8
Sham	135.1	152.8	178.4
	26.0	21.5	27.1
	85.3-181.2	114.9-201.0	133.8-229.3
1 gram	140.0	149.3	175.6
	41.3	43.2	43.5
	85.0-206.9	90.8-217.6	112.3-236.3
2 gram	140.4	147.9	163.4
	26.2	32.3	34.8
	110.5-202.7	113.2-214.5	113.5-234.3
3 gram	125.8	135.4	158.5
	22.9	23.5	23.3
	94.6-165.2	104.6-171.6	125.3-198.2
4 gram	130.5	136.4	149.8
	21.5	22.1	32.5
	90.2-175.4	106.2-186.7	100.7-204.7
5 gram	129.8	130.8	155.5
	33.4	25.1	29.4
	93.9-199.9	99.1-188.8	108.0-210.5

Table 3. Mean ratios (%) of transmitter weights to body weights and standard deviations and ranges of these ratios of each treatment group of westslope cutthroat trout at time of transmitter implantation and 2-week and 6-week stamina trials.

Treatment	Implantation	2 Weeks	6 Weeks
Control	0 -- --	0 -- --	0 -- --
Sham	0 -- --	0 -- --	0 -- --
1 gram	0.77 0.22 0.48-1.18	0.72 0.20 0.46-1.10	0.60 0.16 0.42-0.89
2 gram	1.46 0.24 0.99-1.81	1.41 0.28 0.93-1.77	1.27 0.26 0.85-1.76
3 gram	2.46 0.44 1.82-3.17	2.28 0.40 1.75-2.87	1.93 0.28 1.51-2.39
4 gram	3.15 0.55 2.28-4.44	3.00 0.45 2.14-3.77	2.79 0.62 1.95-3.97
5 gram	4.05 0.83 2.50-5.32	3.94 0.68 2.65-5.04	3.32 0.62 2.38-4.63

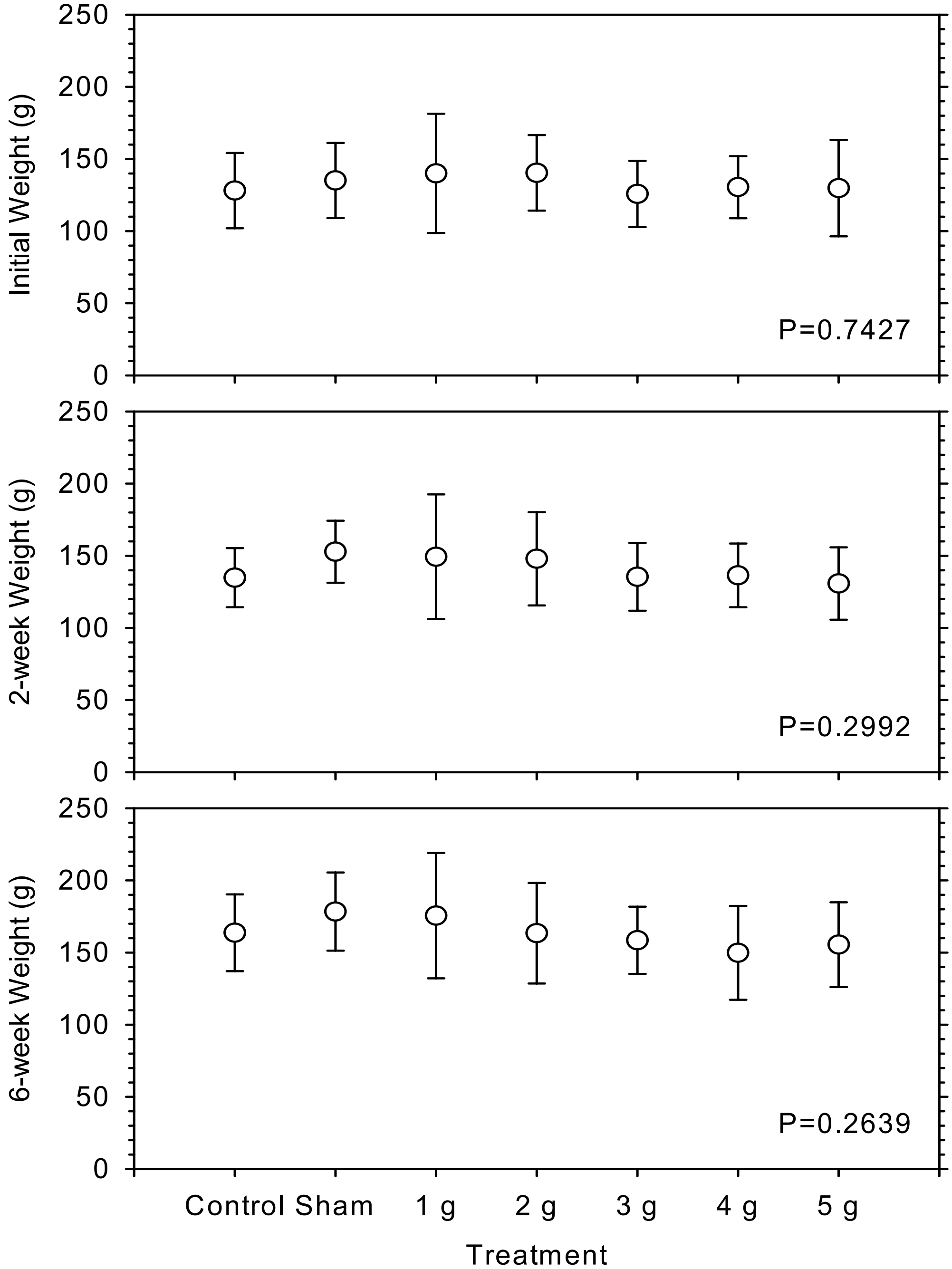

Figure 1. Mean body weights of westslope cutthroat trout implanted with transmitters of various weights (treatments) at time of surgery and 2 and 6 weeks after implantation. Error bars denote ±1 standard deviation.

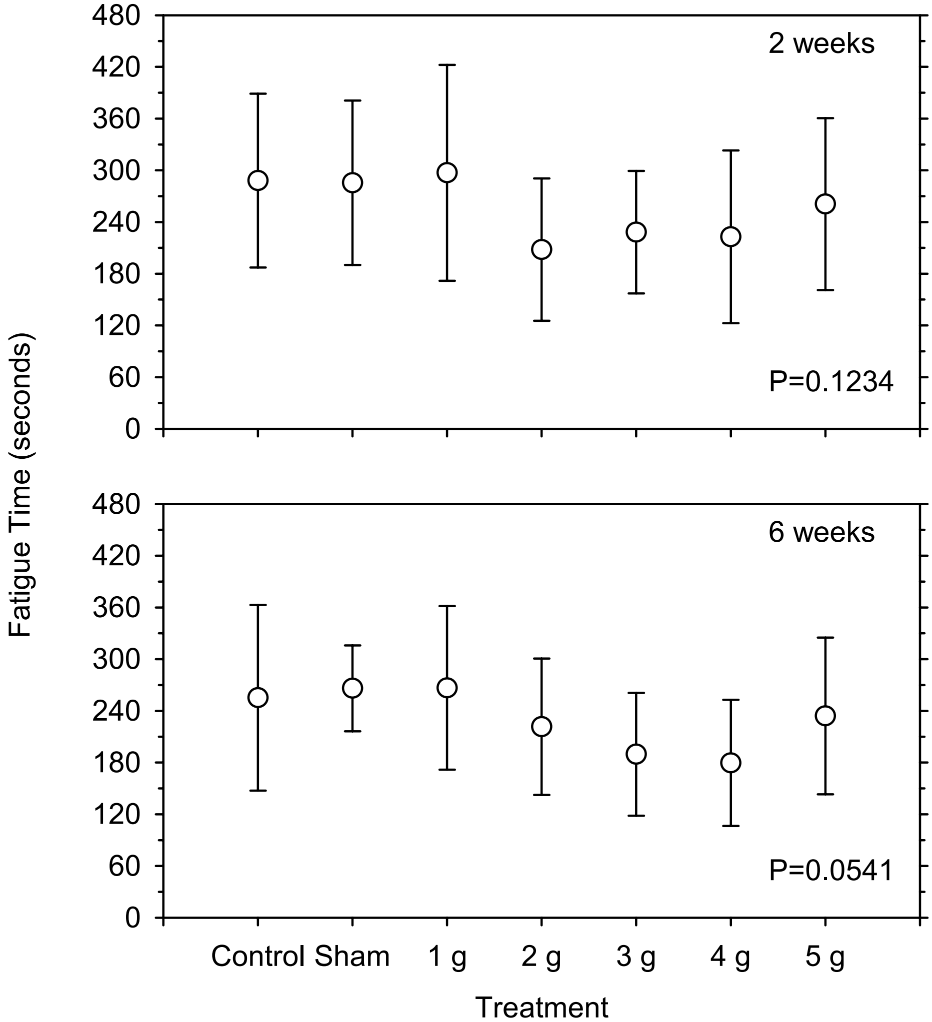

Figure 2. Times to fatigue at 90 cm/second water velocity of westslope cutthroat trout implanted with transmitters of various weights (treatments) at 2 and 6 weeks after implantation. Error bars denote ±1 standard deviation.

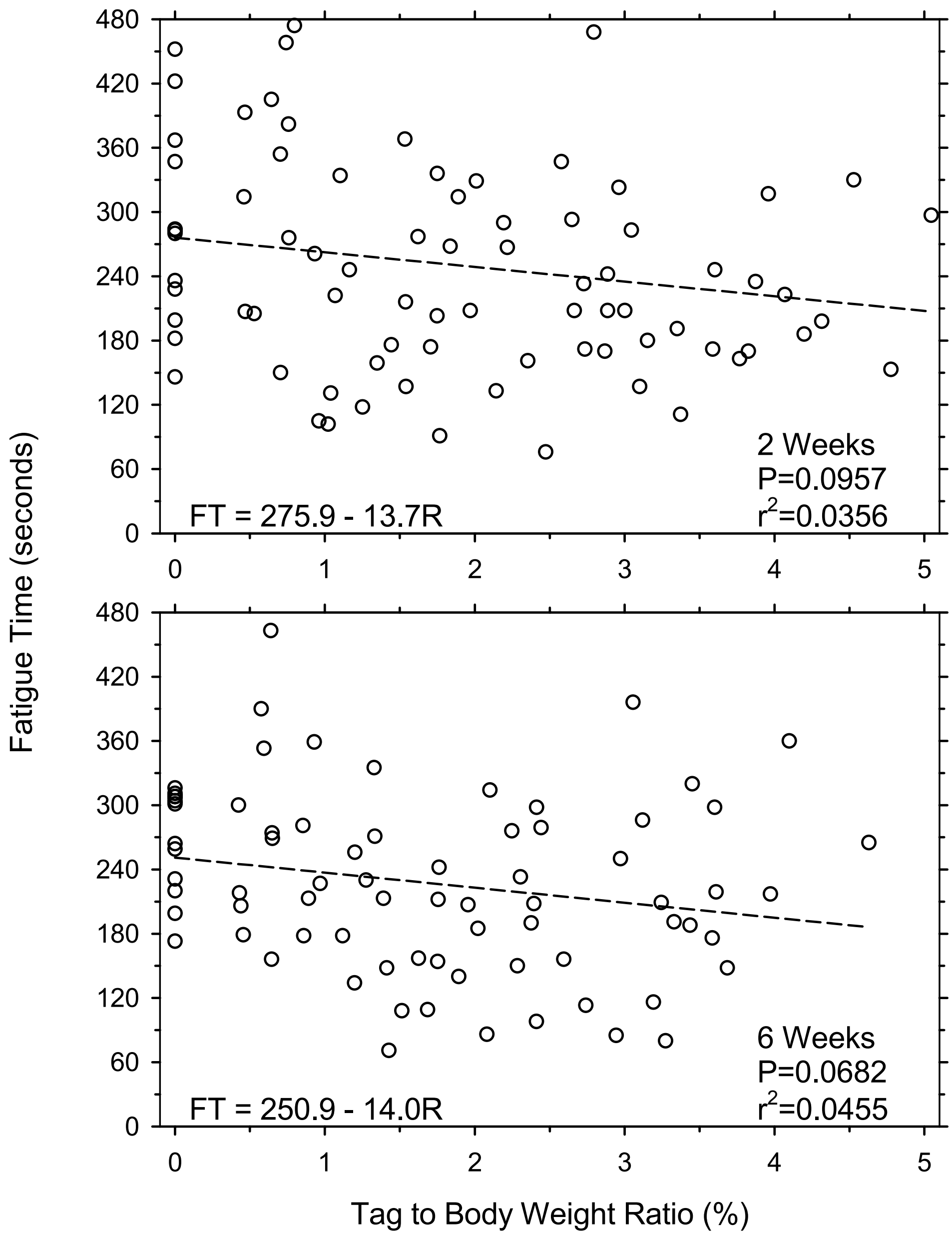

Figure 3. Times to fatigue at 90 cm/second water velocity of individual westslope cutthroat trout implanted with transmitters of various proportions of body weight at 2 and 6 weeks after implantation.

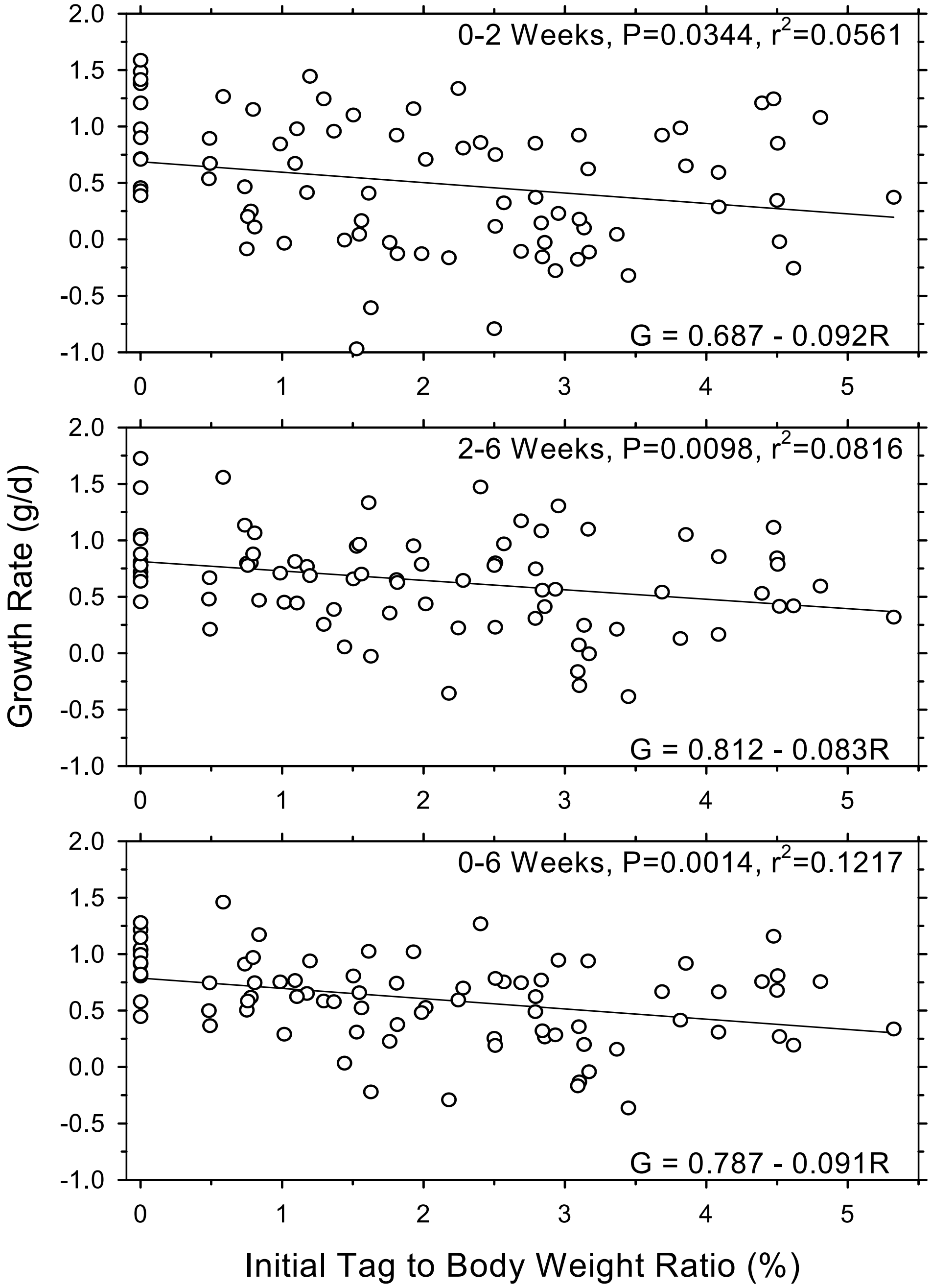

Figure 4. Daily growth rates during the first 2 weeks, 2 to 6 weeks, and all 6 weeks after implantation of individual westslope cutthroat trout implanted with transmitters of various proportions of body weight.